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NEAR FIELD ANALYSIS OF AIRBORNE ANTENNAS,(U)
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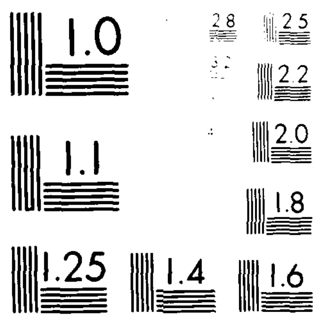
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NEAR FIELD ANALYSIS OF AIRBORNE ANTENNAS

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ElectroScience Laboratory

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16. Abstract (Limit: 200 words)

The radiation pattern analysis of the prolate spheroid based on the efficient UTD and geodesic solutions developed at least partially under previous NASC contracts has been combined with the flat plate scattering analysis in order to simulate complex airborne structures. This includes the junction edge scattering which results at the union between the fuselage (prolate spheroid) and flat plate. This solution is being verified by comparisons with various airborne antenna configurations. In addition, the geodesics for an ellipsoid have been found using a perturbation theory similar to that used for the prolate spheroid. This new ellipsoid configuration will be used to represent the fuselage in future simulation analyses.

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NEAR FIELD ANALYSIS OF AIRBORNE ANTENNAS

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Now that the analysis of airborne antenna patterns has become an accepted practice, the need for more general solutions is becoming very apparent. The basic philosophy here is that one can use the numerical solution to predict the pattern performance for a given application such that one can easily narrow the alternatives down to a few practical solutions. At this point, some type of measurement could be made using either a scale model or the actual aircraft in order to verify the numerical result. Using this approach one can quickly examine various possibilities and determine an optimum solution.

The first major numerical solution for airborne antenna patterns concentrated on using a cylindrical fuselage as described in References [1, 2, 3]. The limitation of the analysis to a cylindrical fuselage resulted for two major reasons: 1) the geodesics on a general curved surface are not straightforward, and 2) the radiation pattern solution for antennas mounted on a general curved surface with torsion was not available. Both of these obstacles have been overcome under the continuating support from the Naval Air System Command (NASC) contracts as summarized in Reference [4].

The geodesics for complex shapes now can be efficiently determined as shown in Reference [5]. Only flat plate structures need to be added to that solution. Note that it has been shown in References [1, 2, 3]

that one can successfully model complex aircraft structures using finite flat plates. A summary of those simulations is shown in Table 1. The interactions between the curved surface diffraction and finite flat plate scattering are the major topics of this effort.

A prolate spheroid was initially chosen to simulate the fuselage for this study, in that its performance is much easier to evaluate based on comparisons with experimental results. The final fuselage simulation model will eventually be an ellipsoid which is presently being examined in terms of an efficient, yet accurate, geodesic solution.

The addition of an isolated flat plate to the prolate spheroid-mounted antenna model was treated in Reference [6]. Some examples of that study are illustrated in Figures 1, 2 . Note that in each case the computed patterns agree very well with the experimental results. The various mechanisms used in that analysis are illustrated in Figure 3 with the individual pattern contributions shown in Figure 4 . The patterns are all normalized to the same total pattern maximum so that one can get a feel for the significance of the various terms.

The isolated plate study just described follows standard high frequency techniques such that one might anticipate the previous verification for the solution; however, the attachment of the flat plate to the prolate spheroid is not straightforward. Note that the flat plate must intersect the spheroid in order to represent, for example, the wing-root section of the aircraft.

The first step in this study was to determine the intersection line between the plate and spheroid which was completed using the method described in Reference [7] . The diffractions from this junction line had to be analyzed before a complete radiation pattern could be computed. It was shown in Reference [8] that one could use a modification of the geodesic solution of Reference [5] to determine the illumination of this curved edge. Further, it was found that the radiation solution of Reference [9] could be used to predict the fields incident upon the edges. The edge diffracted fields, then, simply follow the ordinary edge diffraction results of Reference [10].

With the analysis of the junction edge completed and using edge diffraction concepts presented in Reference [3], the complete radiation pattern for an antenna mounted on the aircraft could be computed using the prolate spheroid fuselage simulation. This solution was, then, applied to previous commercial aircraft simulations for which measured results were already available. Some examples of that verification study are shown in Figures 5-8 for a KC-135 aircraft on which a monopole antenna is placed on the top of the fuselage both forward and above wings as shown in Figure 9. The significance of this new solution is that the spheroid model provides the proper polarization and curvature effects as opposed to the cylinder which models only one curvature. Note that the surface geometry dictates the polarization of the radiated field [9].

Now that the numerical solution composed of the prolate spheroid fuselage and flat plate structures is rounding into shape, this model

is being applied to solve numerous complex aircraft problems. Specifically, the Rome Air Development Center is interested in modelling fighter aircraft with complex stores attached as well as interfacing the code with an adaptive array analysis. This study has illustrated some problem areas associated with airborne adaptive array systems as well as indicating various interesting solutions.

The NASA (Langley, Va.) is interested in using the code to analyze the radiation characteristics of antennas mounted on private aircraft. In their application, it was apparent that a model for the windshield had to be added to the solution. As a result, a thin dielectric solution is being constructed and will be used in the aircraft code to simulate composite materials, radomes, absorber, windshields, etc. In addition, a frequency loop has been added to the computer code so that one can very efficiently obtain the frequency spectrum data which can be easily transformed in order to obtain time waveforms. This aspect of the solution is very interesting in terms of various communication system questions such as the effects of wide bandwidth on operational adaptive array systems.

We have successfully completed our numerical solution for the analysis of airborne antenna patterns using a prolate spheroid to simulate the fuselage and flat plates to model the other appendages. Recall that the flat plate simulations of wings, stabilizers, engines, and stores was very successfully developed and verified under our previous contracts. However, the prolate spheroid representation of the fuselage is not general enough to satisfactorally approximate the wide

variety of military aircraft. Note that the prolate spheroid was analyzed initially to illustrate how one can use a simplified geodesic method along with the general GTD radiation solutions to obtain the complete patterns for an antenna mounted on a doubly curved surface. The inadequacy associated with the prolate spheroid results from its circular cross-section. It has been shown in Reference [1] that an elliptic cross-section is necessary to successfully simulate the wide variety of aircraft fuselage shapes. Since an elliptic cross-section, as well as profile is needed, it is rather obvious that one must use an ellipsoid in order to simulate a general fuselage. Under our present contract, we have developed the simplified geodesic solutions needed to generate a general radiation pattern analysis for an antenna mounted on an ellipsoid. The analysis for the geodesic solution is described in a quarterly report [11].

As a continuation of the present research effort, this geodesic solution for the ellipsoid will be employed to construct the general radiation solution along with flat plates which will be used to simulate the various appendages as done earlier for the prolate spheroid model. Once this numerical solution is completed, it will be verified based on numerous comparisons with experimental results. Most of these comparisons will be in terms of actual aircraft simulations that have been used for in the past for verification purposes.

The development of the ellipsoid fuselage model should complete the basic research effort associated with the general topic of airborne

antenna pattern analysis in terms of treating perfectly conducting structures. However, that does not imply that all the basic research problems in this general topic area have been resolved. For example, there has been a great deal of interest recently in terms of analyzing the scattering properties of dielectric structures such as an aircraft windshield, an absorber panel, or composite material. In order to treat these types of problems, a high frequency GTD solution for the scattering from finite, three-dimensional, lossless or lossy, dielectric panels has been postulated in Reference [12]. This solution will be added to the airborne antenna pattern analysis and verified using actual aircraft simulations. This addition to our numerical solution will provide a very significant improvement over our previous codes in that a whole new class of problems can, then, be simulated and studied.

Table I
Various aircraft modeled recently using the multiple plate simulation solution

Aircraft	Antennas Studied	Aircraft Structures Simulated	Conclusions
F-4	Blade, Monopole	Wings, Engines, Stores, Missiles, Fuel Tanks, Bombs	Compares well with measurements
A-10	4-Element Blade Array	Wings, Engines, Antennas, Stores	Compares reasonably well with measurements (model was not complete)
C-141	Monopole, slots	Wings, Vertical Stabilizer, T-Tail	Compares well with measurements
Cessna 402	Monopole	Wings, Wing Tanks, Engine	Compares well with measurements
Beechcraft Baron	Monopole	Wings, Engine, Props	Compares well with measurements
Missile	Slot, Slot array	RAM Jets	Compares well with measurements

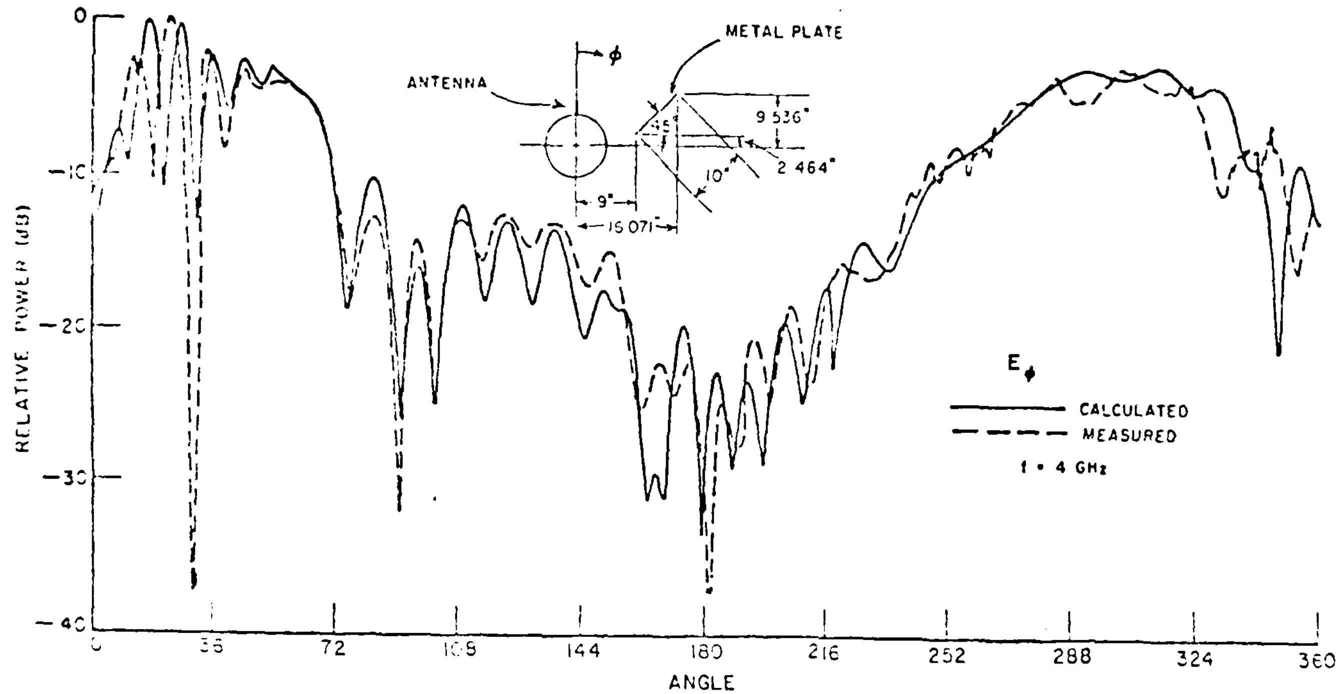

Figure 1. Roll plane ($\theta_c=0^0$, $\phi_c=0^0$, $\theta=90^0$) patterns for a 0.25" monopole mounted at $\theta_s=90^0$ on a 2λ x 4λ spheroid.

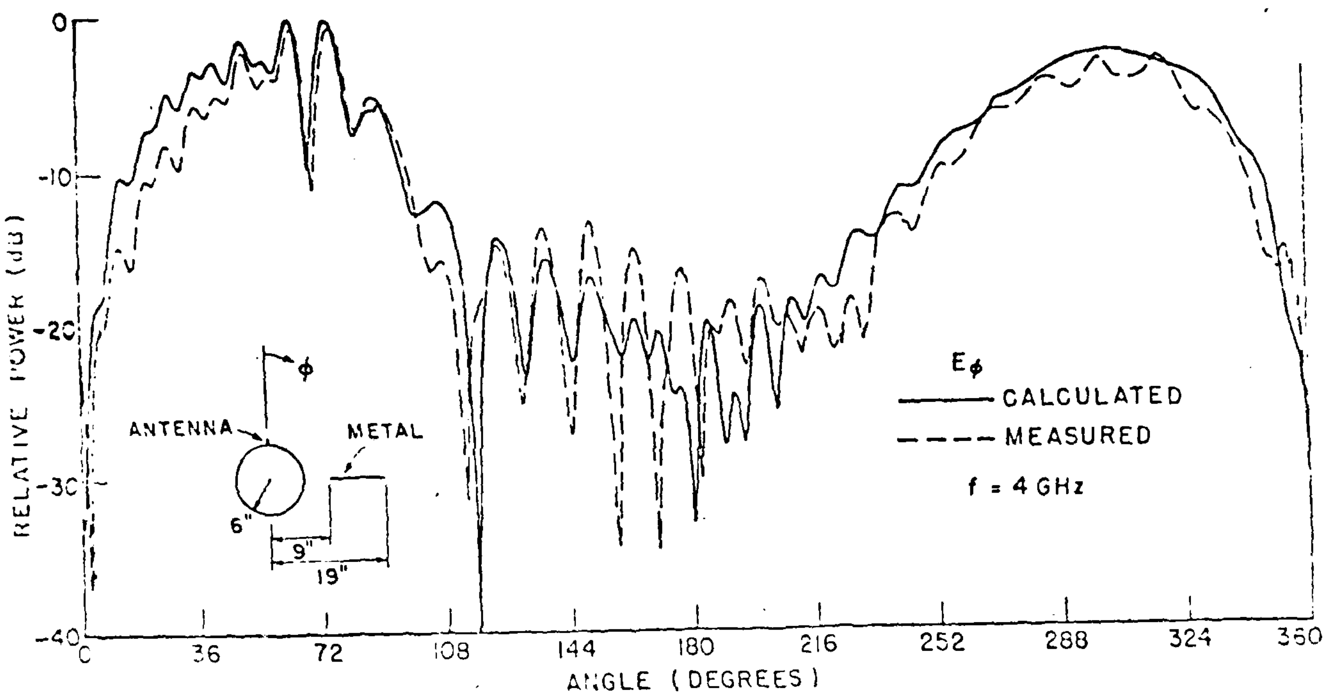

Figure 2. Roll plane ($\theta_c=0^0$, $\phi_c=0^0$, $\theta=90^0$) patterns for a 0.25" monopole mounted at $\theta_s=90^0$ on a $2\lambda \times 4\lambda$ spheroid.

SOLUTION IS OBTAINED BY SUPERPOSITION
OF THE FOLLOWING FIELDS:

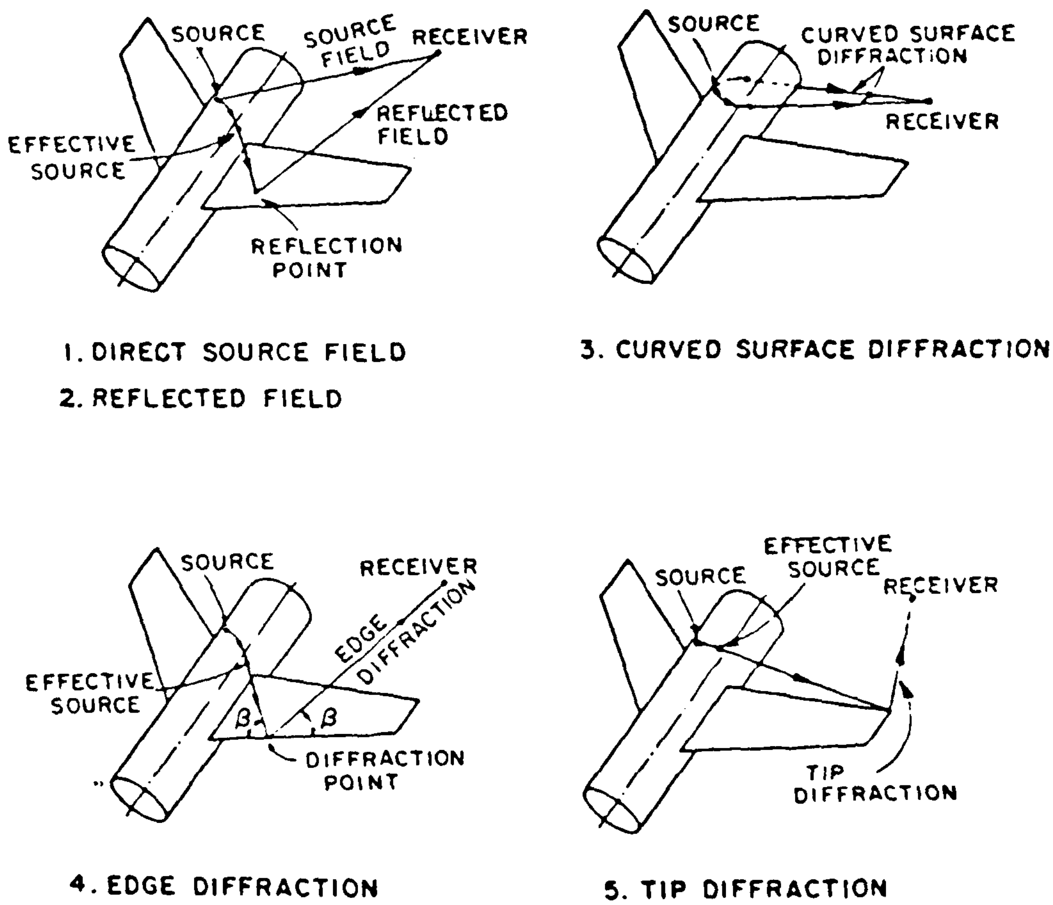

Figure 3. Various terms used in cylinder/plate model.

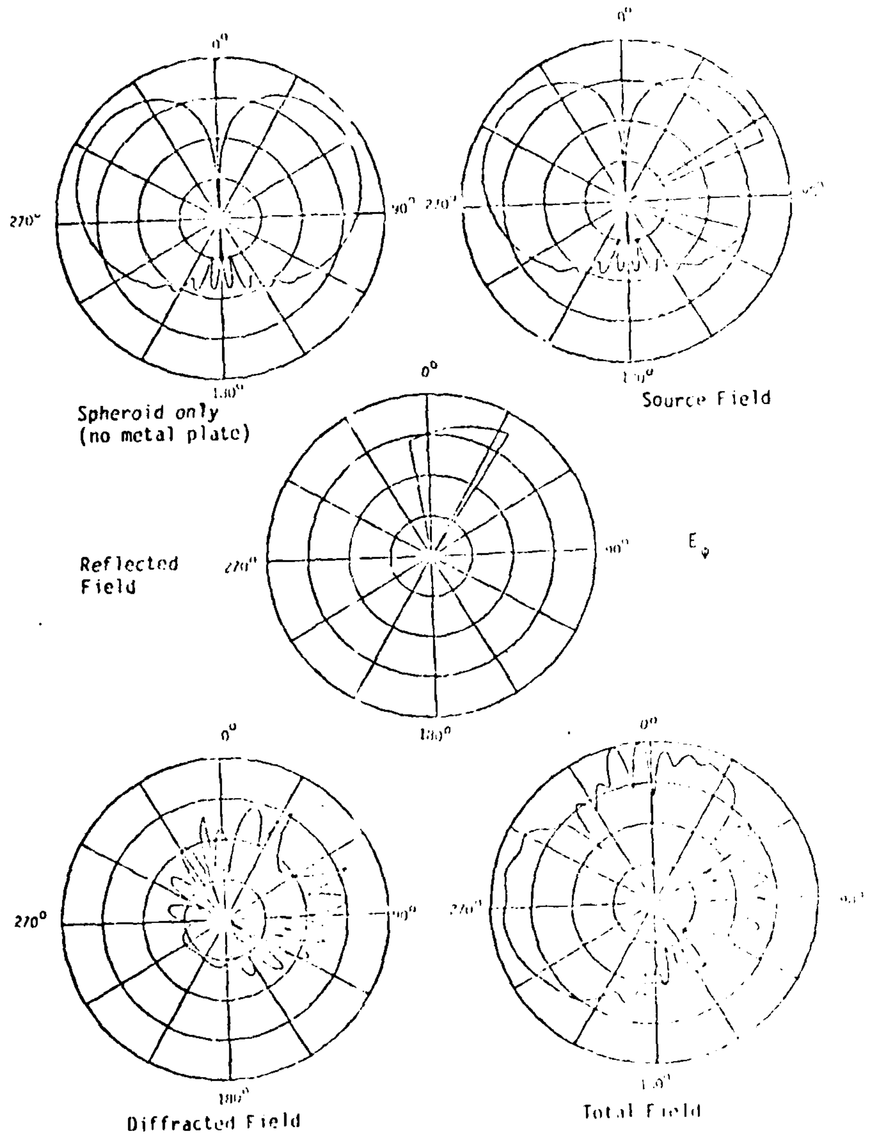

Figure 4. Calculated radiation patterns (θ_c=0°, ϕ_c=0°, θ=90°) for a 0.25" monopole mounted at θ_s=90°. The metal plate is a 10" x 10" square.

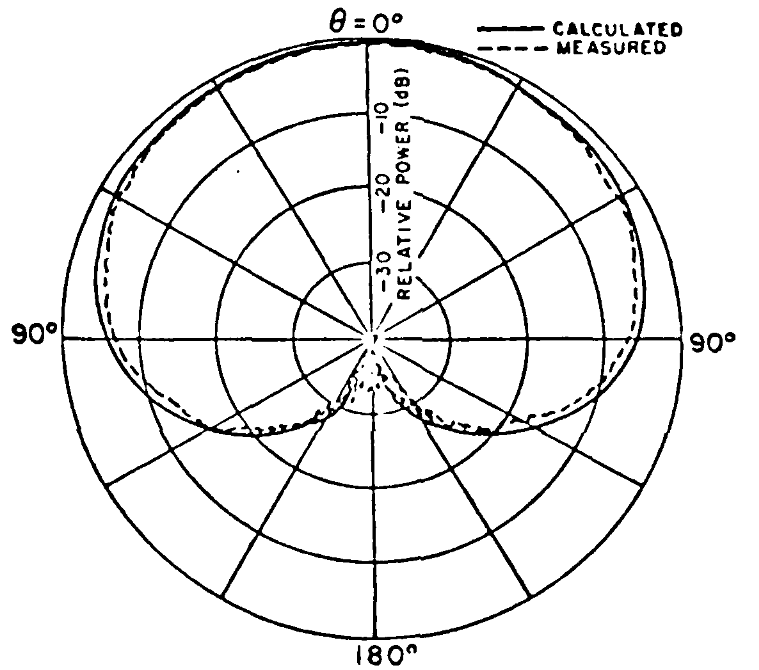

Figure 5a. Roll plane pattern (E_ϕ) for a KA-band axial waveguide forward of the wings.

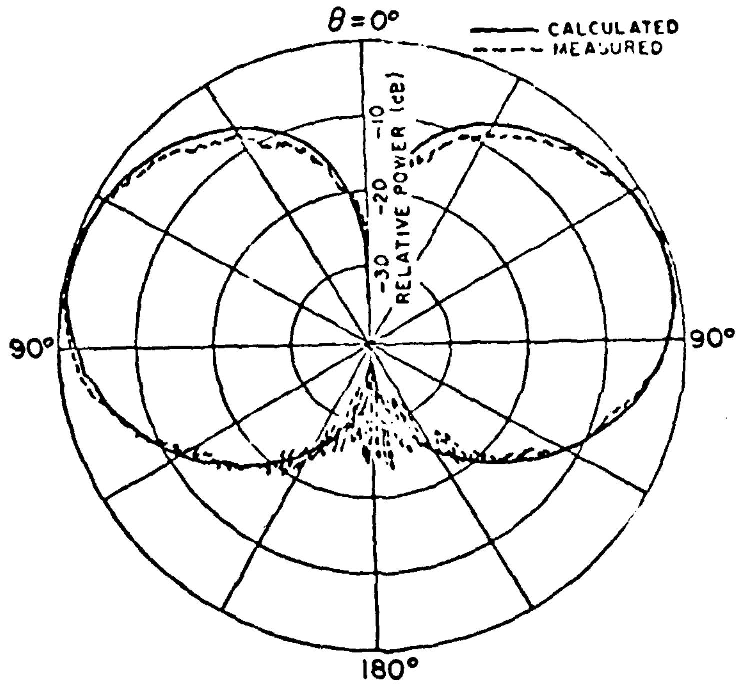

Figure 5b. Roll plane pattern (E_ϕ) for a $\lambda/4$ monopole forward of the wings.

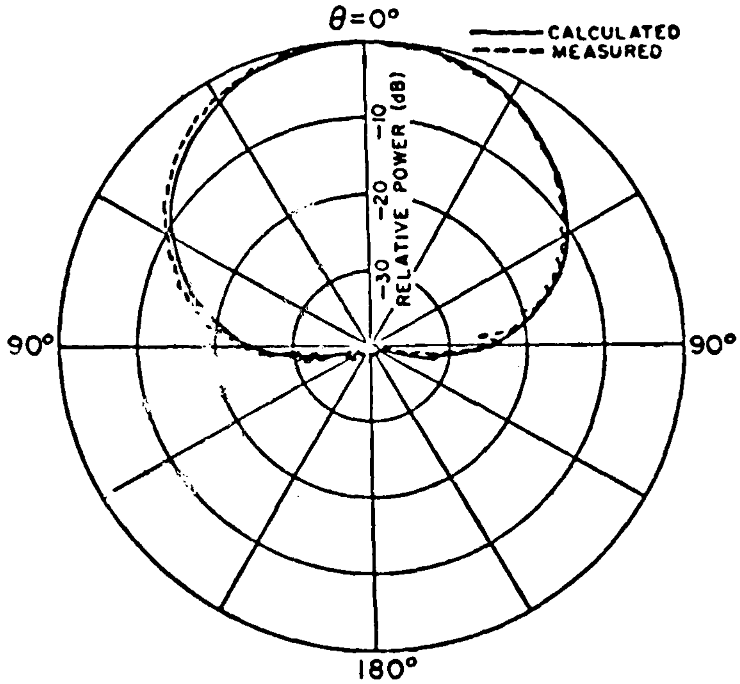

Figure 5c. Roll plane pattern (E_θ) for a KA-band circumferential waveguide forward of the wings.

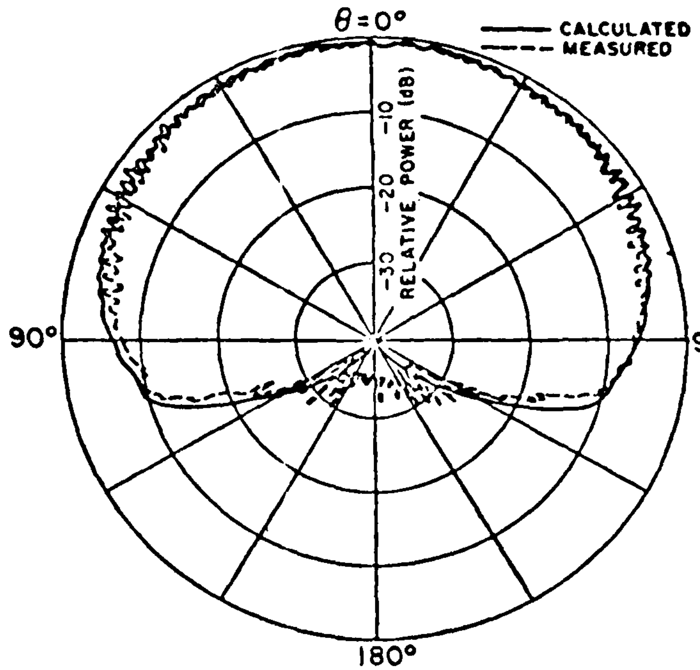

Figure 6a. Roll plane pattern (E_{ϕ}) for a KA-band axial waveguide above the wings.

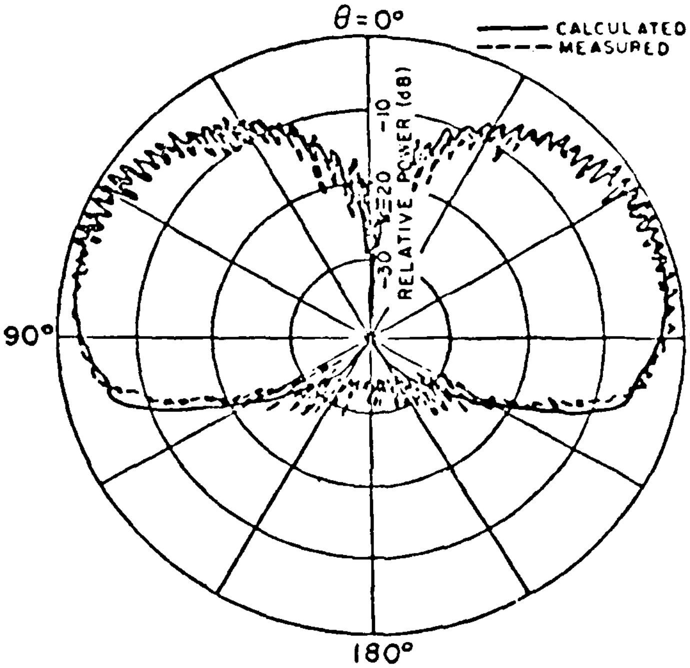

Figure 6b. Roll plane pattern (E_ϕ) for a $\lambda/4$ monopole above the wings.

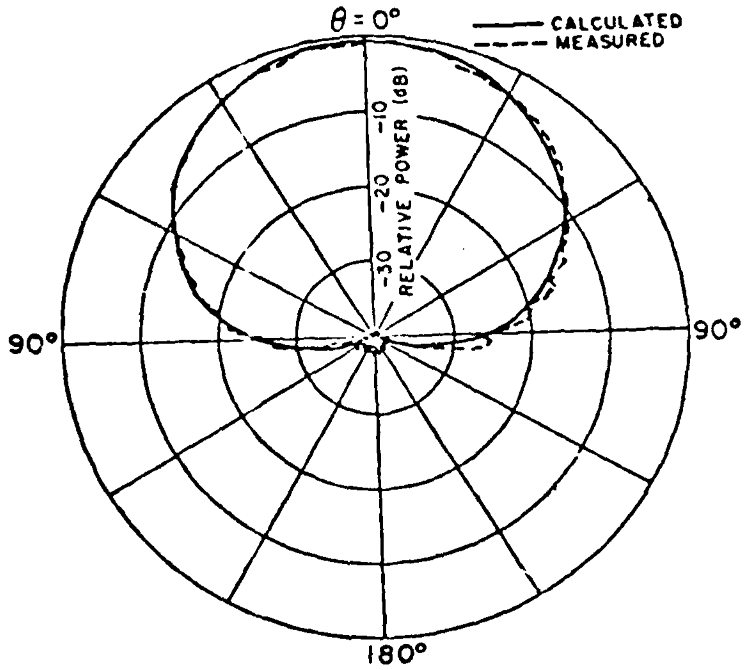

Figure 6c. Roll plane pattern (E_θ) for a KA-band circumferential waveguide above the wings.

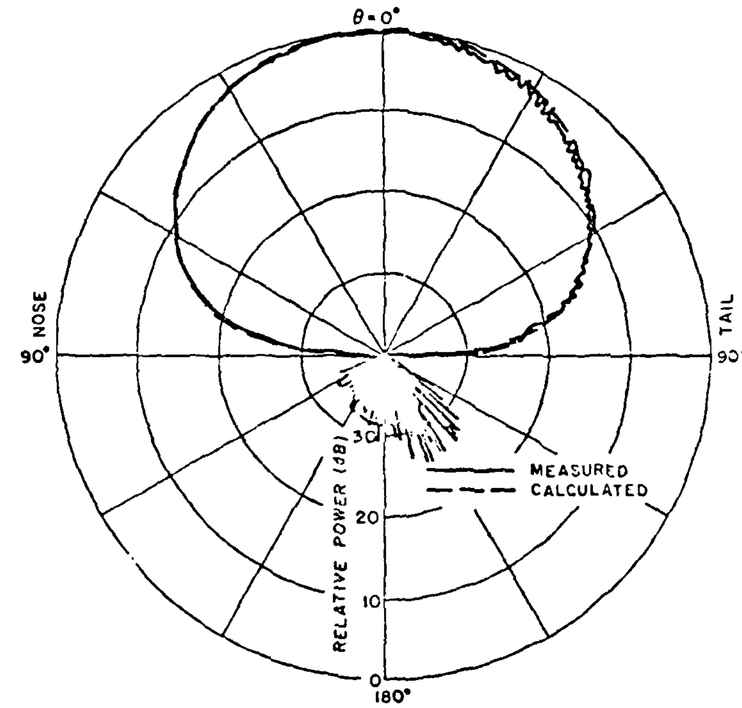

Figure 7a. Elevation plane pattern for an axial KA-band waveguide mounted forward of the wings on a KC-135 aircraft.

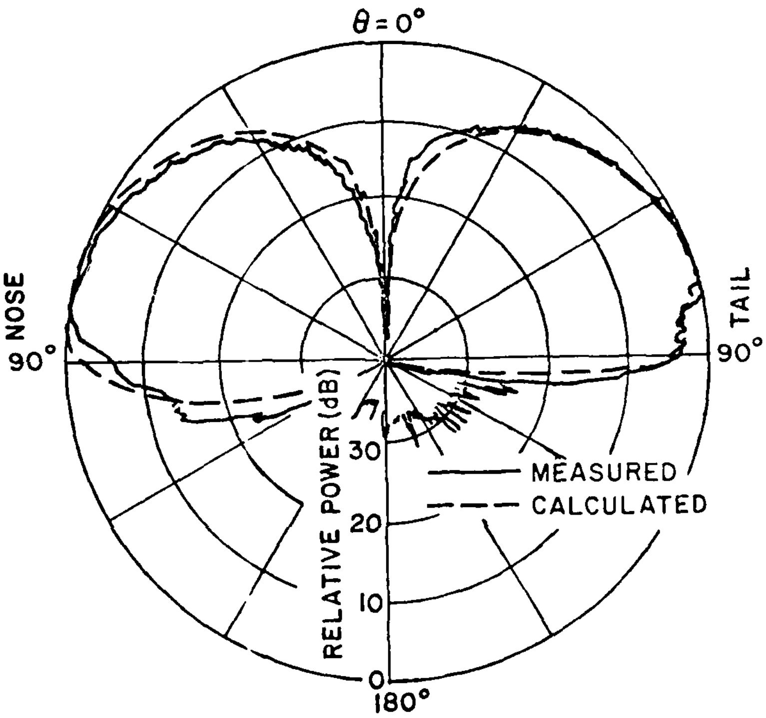

Figure 7b. Elevation plane pattern for a $\lambda/4$ monopole mounted forward of the wings on a KC-135 aircraft.

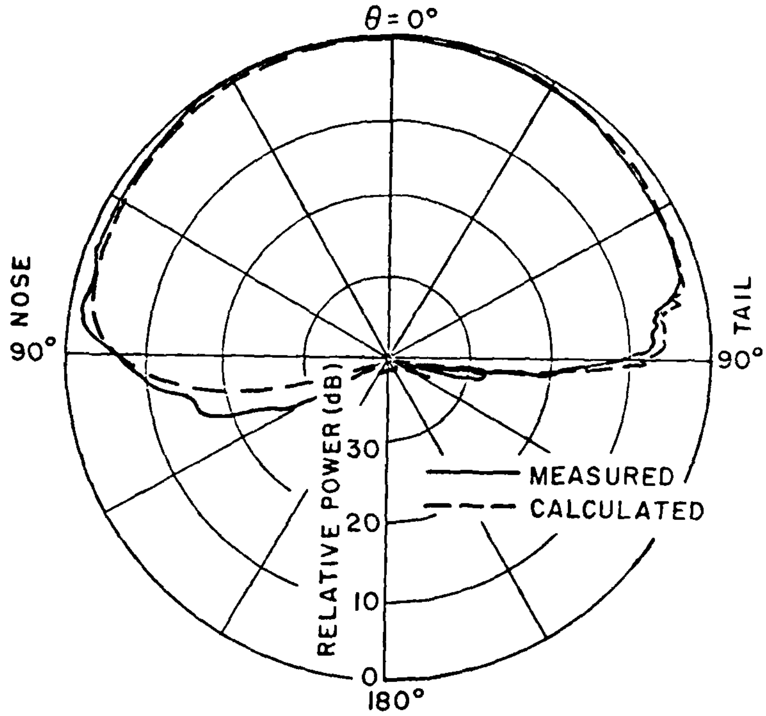

Figure 7c. Elevation plane pattern for a circumferential KA-band wave-guide mounted forward of the wings on a KC-135 aircraft.

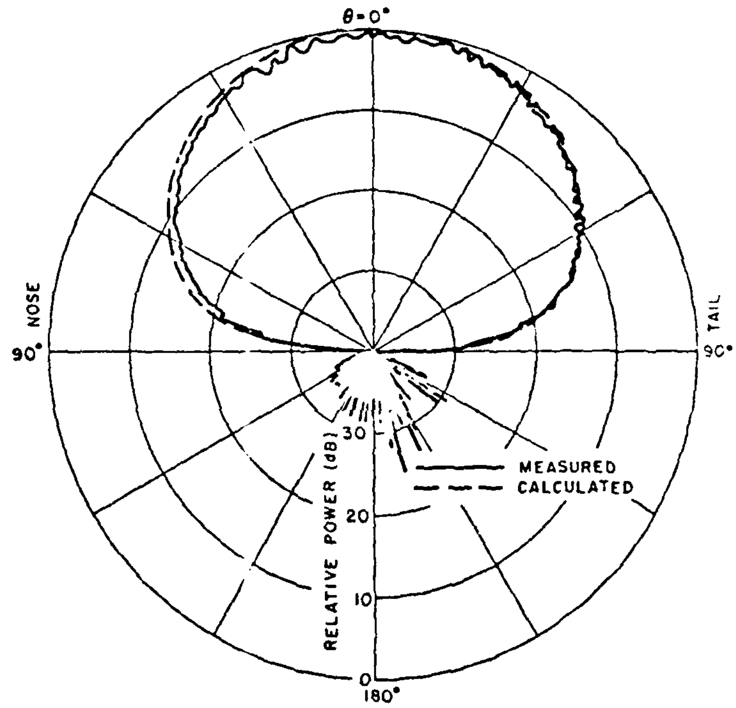

Figure 8a. Elevation plane pattern for an axial KA-band waveguide mounted above the wings on a KC-135 aircraft.

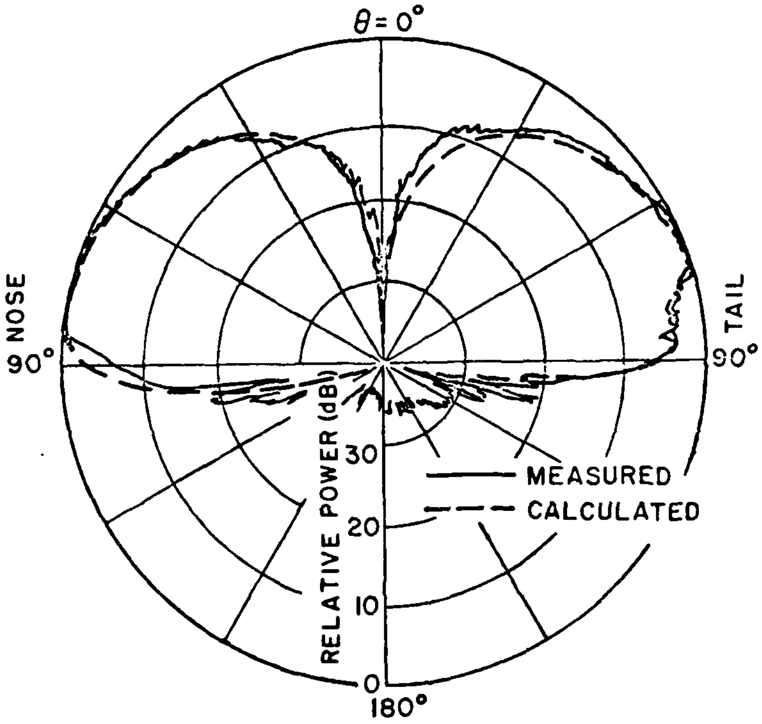

Figure 8b. Elevation plane pattern for a λ/4 monopole mounted above the wings on a KC-135 aircraft.

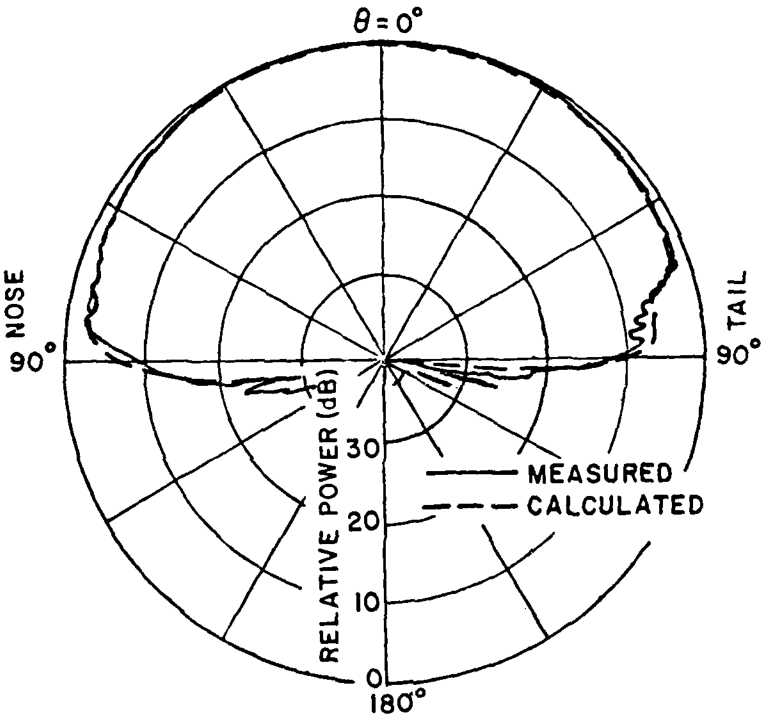

Figure 8c. Elevation plane pattern for a circumferential KA-band waveguide mounted above the wings on a KC-135 aircraft.

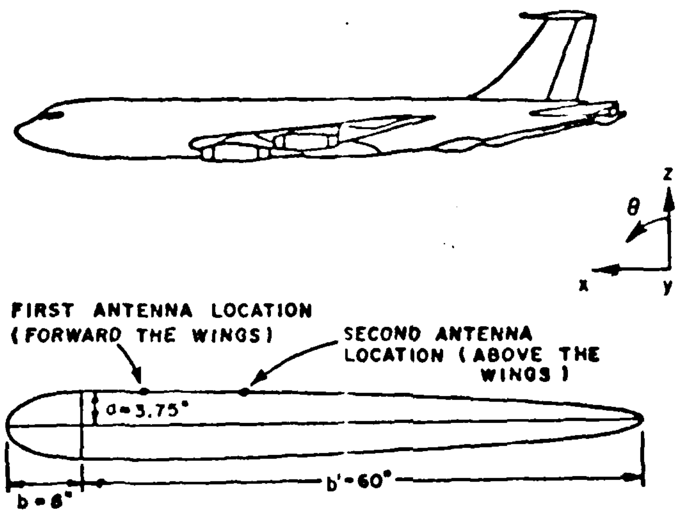

Figure 9. Theoretical model of KC-135 aircraft.

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